# EFFECT OF THE $N = 108$ "DEFORMED SHELL" ON NUCLEAR PROPERTIES

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Experimental facts related to the closure of a subshell for $N = 108$ are summarized. It is suggested that this closure stabilizes the deformed shape of even W and Os nuclei.

In 1966 Strutinsky has pointed out [1] that the existence of the shell effects is not necessarily limited to the sphericity of the nuclear shape but is a more general property of single particle levels also in a deformed field. The so-called "deformed shells" are related to the local changes of the single particle level density near the Fermi surface. Qualitatively it may be expected that the next deformation beyond $\beta = 0$ for which the shell effects will appear is $\beta \approx A^{-1/3}$ when the proton or neutron number lies approximately half-way between two shells with $\beta = 0$. Quantitative calculations of the single particle levels in a deformed field performed, *e. g.*, by Nilsson *et al.* [2] show the expected position of these shells as a function of the proton or neutron number, and deformation.

It is interesting to know how the low density of the single particle levels in a deformed field affects the nuclear properties. Although the effect of the deformed neutron shell with $N = 152$ on the spontaneous fission half-lives is well known (see *e. g.* Ref. [3]), the experimental evidence for other theoretically predicted sub-shells has been given little study. One can expect that this effect will be particularly pronounced in the case of transitional nuclei. The properties of these nuclei are strongly affected by small changes of the potential energy surface which in turn depends on the single particle level occupation. In this note an attempt is made to summarize the effects presumably related to the theoretically predicted [2] energy gap in the vicinity of $N = 108$ ($\beta \approx 0.1$–$0.3$, see Fig. 1) for even nuclei in the Os region. Some of these effects were already signallized [4–6] but will be repeated here for the sake of completeness. The full list of references to the experimental data referred to here is to be found in a recent review [7] by the same author.

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The experimental facts related to $N = 108$, are listed below.

a) The $2_1^+$ state energy has a minimum for W and Os nuclei with $N = 108$. For Pt nuclei this minimum is reached exactly for the middle of the shell ($N = 104$), but the change of $E_{2_1^+}$ between $N = 110$ and $N = 108$ is very pronounced (see Fig. 2).

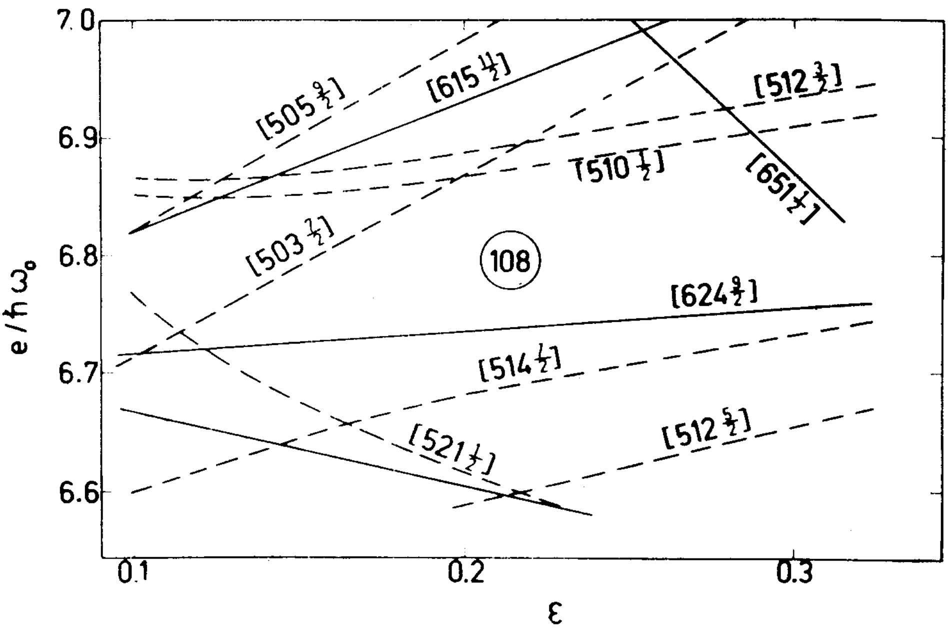


Fig. 1. Single-neutron levels for $175 \leqslant A \leqslant 190$ (*cf.* Ref. [2])

b) The ratio $E_{4_1^+}/E_{2_1^+}$ has a maximum value (closest to that predicted from the rotational model) for W and Os nuclei with $N = 108$ (see Fig. 3).

c) The ratio $E_{2_2^+}/E_{2_1^+}$ has a maximum for W and Os nuclei with $N = 108$ (see Fig. 4). For Pt nuclei this maximum is not observed, but the energy of the $2_2^+$ state in these nuclei can be strongly perturbed by a close lying $2_3^+$ state [8].

d) The ratio of the transition probabilities $B\left(E2; \frac{2_2^+ \to 0_1^+}{2_2^+ \to 2_1^+}\right)$ from the gamma band to the ground state band has a maximum (value closest to the unperturbed rotational value of 0.7) for W, Pt and probably Os isotopes with $N = 108$ (see Fig. 5).

e) The excitation energy of the $K = 2$ octupole band in W nuclei has a maximum for ${}^{182}_{74}W_{108}$. The B(E3) value for the excitation of the $3^-$ level in this band has a minimum for the same nucleus [9].

f) A sharp change of the function $J = f(\omega^2)$ is observed when $N$ changes from 108 to 110 for Pt nuclei (see Fig. 6); such a change but less pronounced is also observed for Os and W nuclei [7]. $J$ is here the moment of inertia and $\omega$ the rotational frequency (*cf.* [10, 11]).

g) A broad local minimum around $N = 108$ has been found in the Os, Ir, Pt, Au average beta strength function [4]. This minimum can be related to the energy gap existing between $N = 108$ and $N = 110$ single particle orbit. Owing to this energy gap a higher

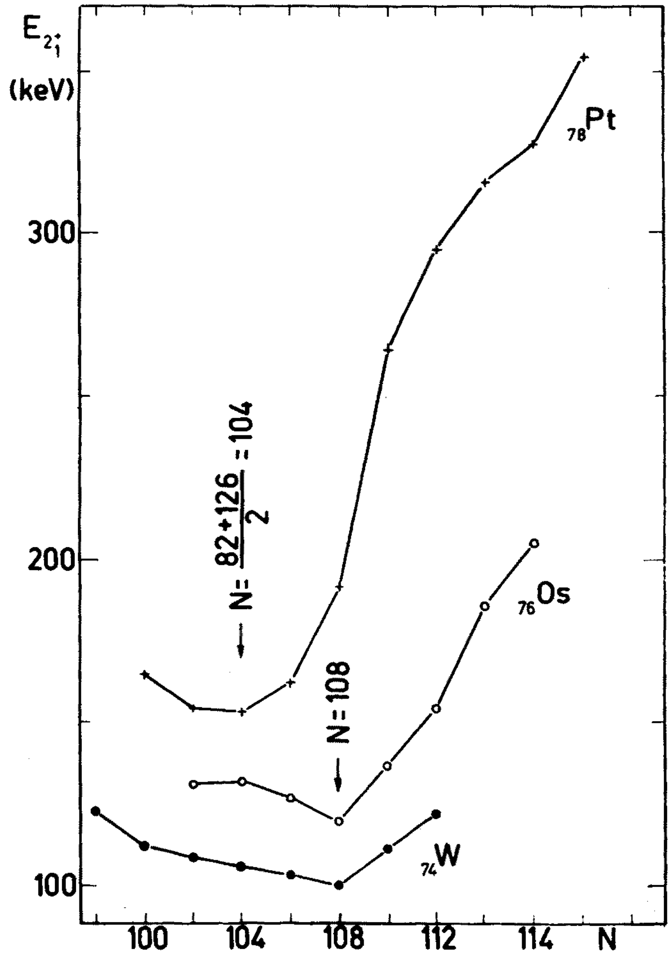


Fig. 2. Energies of the $2_1^+$ state *vs* neutron number

excitation energy of the corresponding neutron states is obtained to which the allowed or first forbidden transition proceeds. The increasing excitation energy drasticaly reduces the average beta strength function.

h) One observes a "local maximum" of the separation energies $S_n$ and $S_{2n}$ for $^{180}_{72}Hf_{108}$ [6] and of $S_n$ for $^{182}_{74}W_{108}$ [12]. The separation energies for these isotopes are larger than those expected from the linear interpolation of the data obtained for other isotopes of these elements.

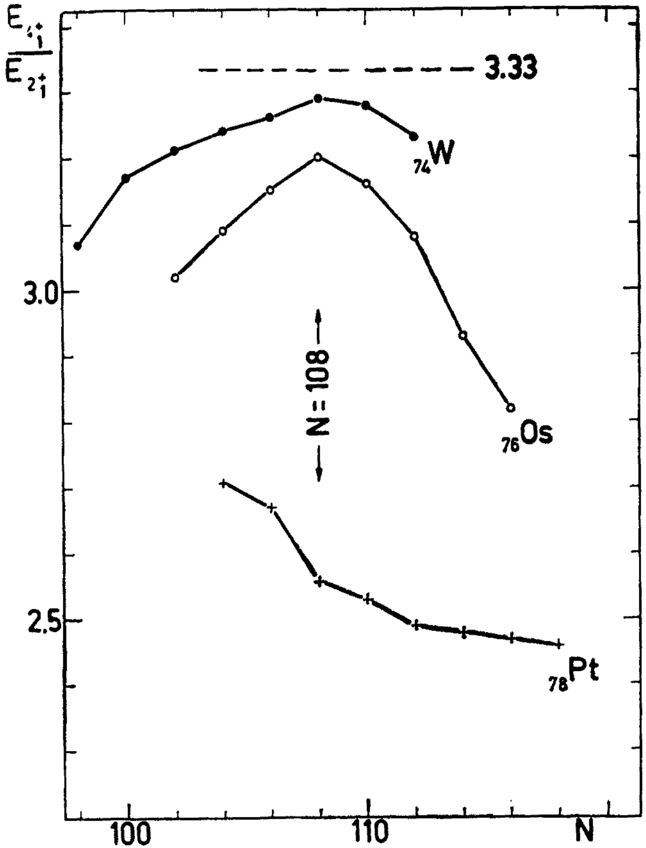


Fig. 3. Ratio $E_{42}^{+}/E_{21}^{+}$ *vs* neutron number

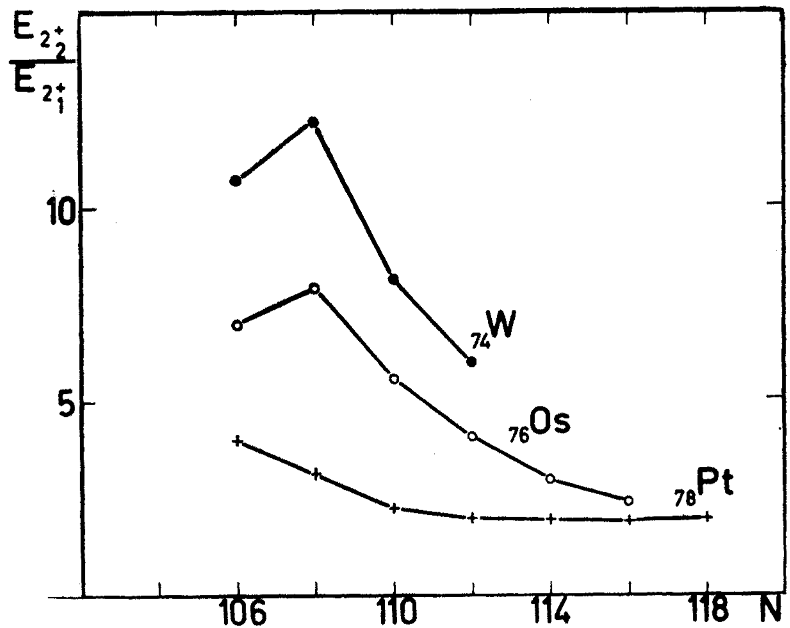


Fig. 4. Ratio $E_{22}^{+}/E_{21}^{+}$ *vs* neutron number

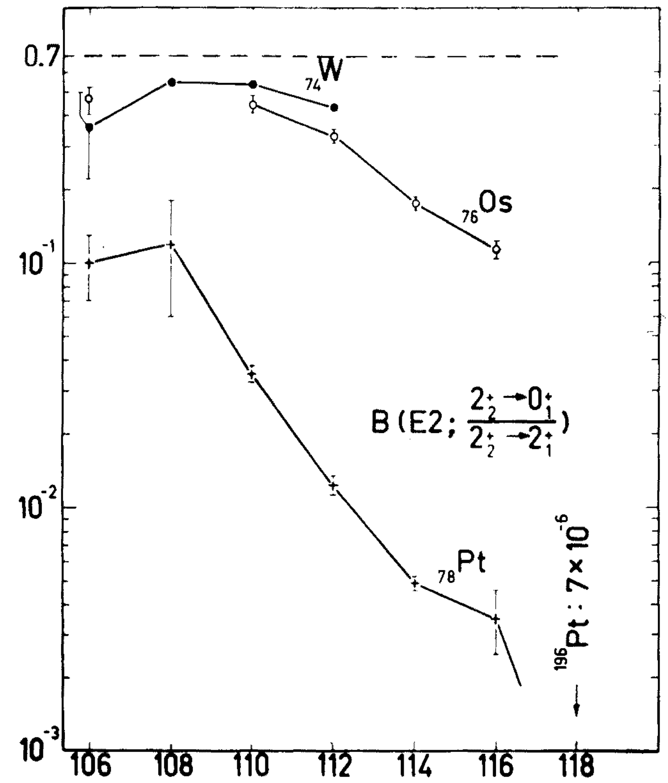


Fig. 5. Ratio of the reduced transition probabilities from the gamma band to the ground state band

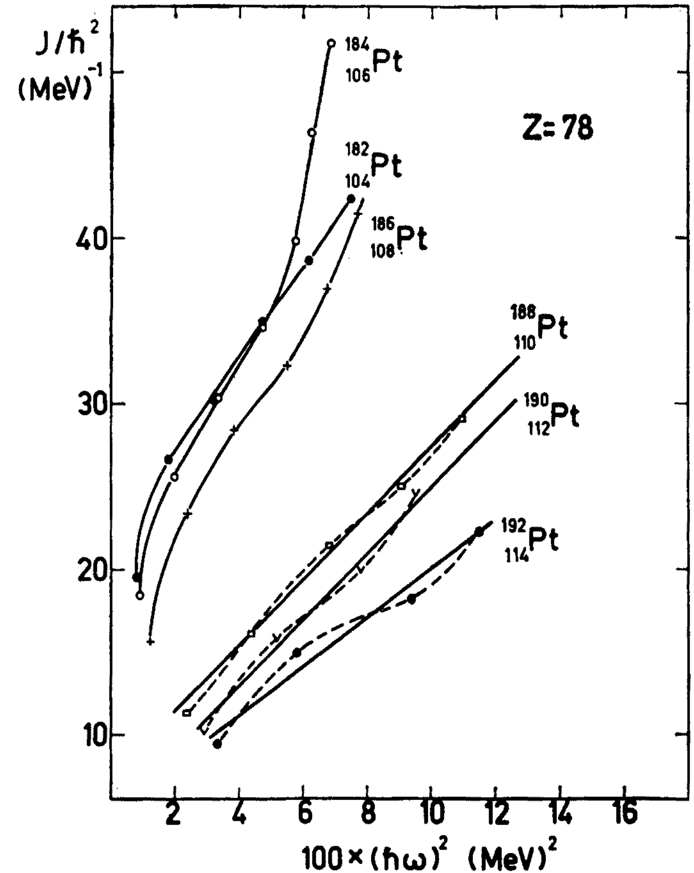


Fig. 6. Moment of inertia of the ground state band plotted *vs* square of the rotational frequency (Pt isotopes)

From some of these experimental facts it follows that for $N = 108$ the deformed shape is the most stable one, at least for W and Os isotopes. Therefore it may be expected that the effect of this neutron number should reveal itself also in the theoretically calculated deformation energy for these isotopes. However, in a recent calculation [13] of the deformation energy based on the pairing + quadrupole model this energy was found to vary smothly with N in the vicinity of $N = 108$. It might be supposed that one of the reasons for this is the neglection in the calculations of the hexadecapole deformation, important in this mass region.

In the Pt nuclei the effect of the prolate-oblate shape transition [14] can mask some of the effects observed for Os and W nuclei.

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Note added in proof: In the light Pt nuclei a low lying $O_2^+$ state was recently identified [15] The energy of this state has a minimum for $^{186}_{178}Pt_{108}$. It is possible that these states are related to the pairing quadrupole vibrations [16].

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